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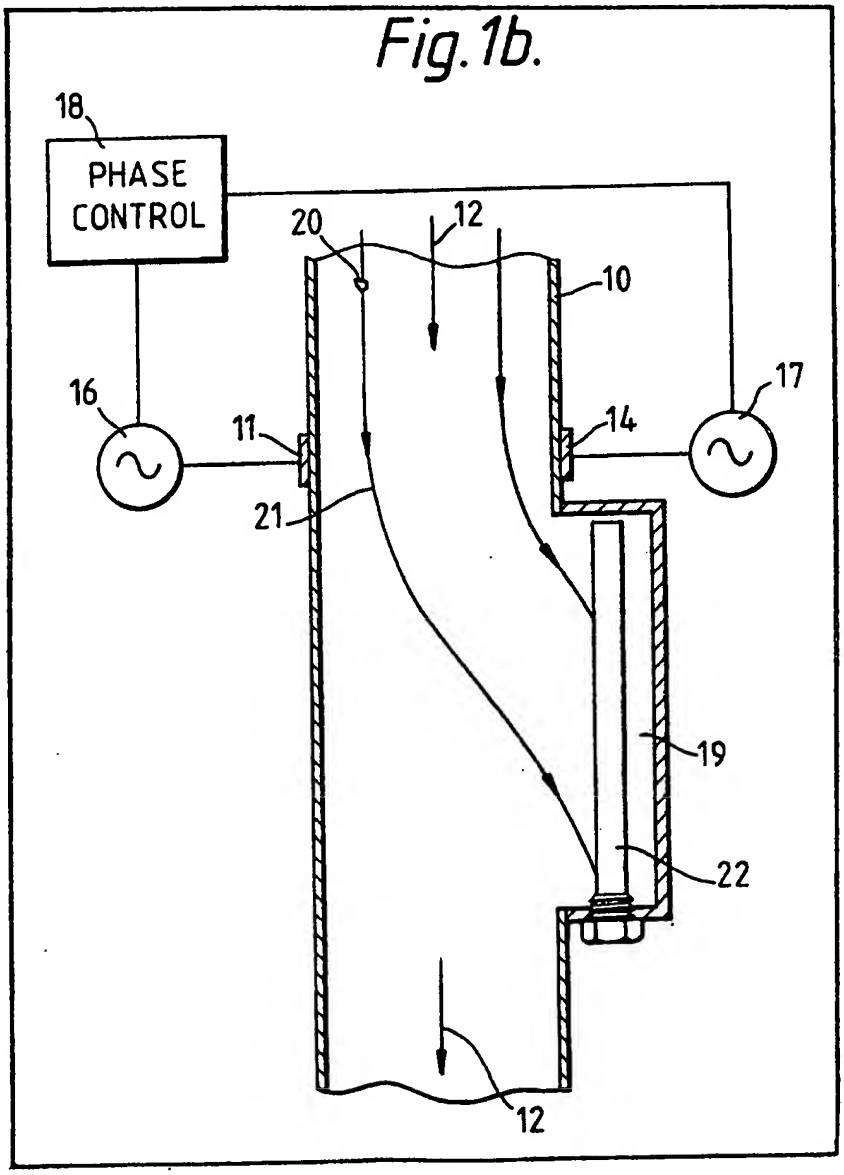
(54) **Separating particles from fluid**

(57) A fluid (12), such as lubricating oil, flowing in a pipe (10) is subjected to a drifting standing wave set up between transducers (11 and 14) by interference of acoustic beams, causing entrained particles (20) to be diverted laterally to a collection zone (19). Zone (19) may include a magnet (22) which retains the particles. The size range of particles deflected by the wave depends on the wave length.

Fig. 1b.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig. 1a.

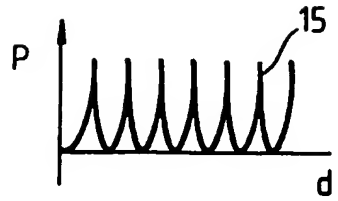
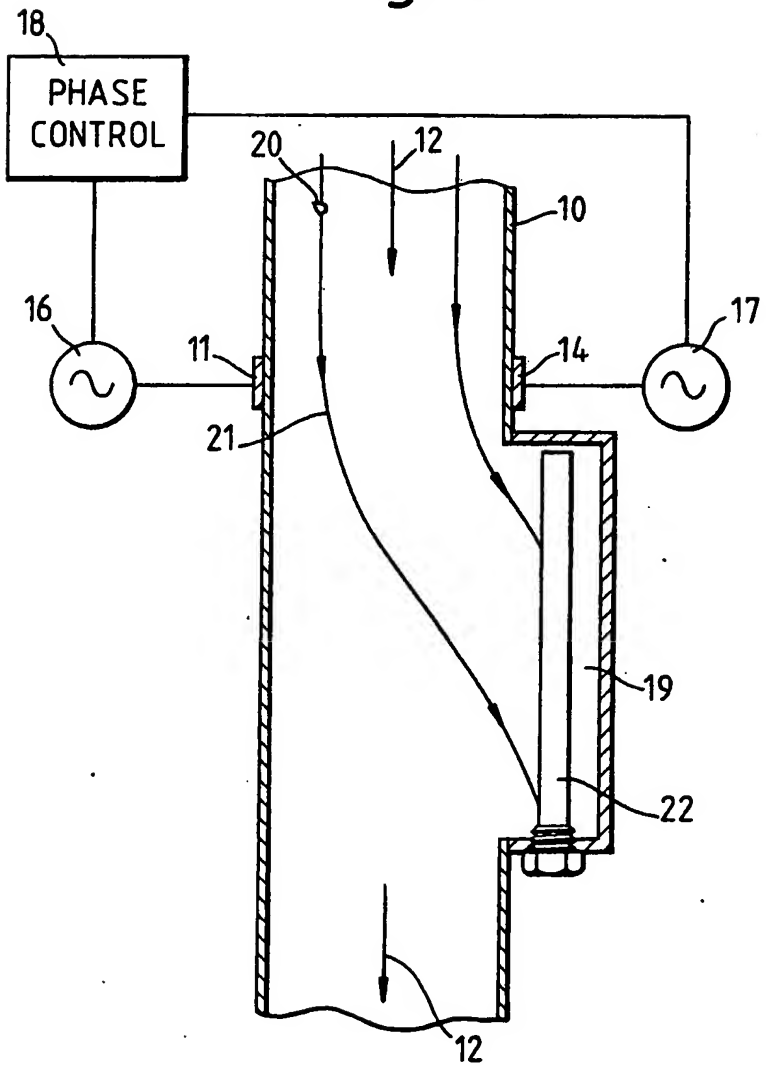


Fig. 1b.



SPECIFICATION

Improvements in or relating to filters

This invention relates to filters for separating particles from fluids.

Techniques which are well known for the separation of particles from a flowing fluid are placement of an element arranged to catch the particles in the flow, or diversion of the flow through a cartridge containing such an element, or guiding the flow such that particles carried by the flow are unable to follow and are separated by centrifugal effects.

Filters of the element type have the disadvantage of restricting fluid flow and are prone to clogging. Centrifugal filters are only practical if rotation of a magnitude capable of diverting particles from the flow can be set up without damage to the fluid and as such are limited to the separation of fairly large particles.

Current studies of lubricating systems suggest that filtration down to a particle size of at least 3μm absolute particle size is desirable, and this requirement may well become more stringent as increased demands are placed upon lubricating systems, such as the lubricating systems of high performance engines. This requirement represents the limiting performance of conventional filters and particular care has to be taken in the design of centrifugal filters operating at this limit to avoid mechanical damage to the long chain molecules which are present in modern lubricating oils.

According to the present invention a filter for the separation of particles from a flowing fluid includes:

means for generating acoustic beams within the fluid which interfere with the flow to set up a standing wave pattern across the direction of fluid, the standing wave producing pressure gradients within the fluid to divert particles carried by the fluid; and means for controlling the generation of the acoustic beams to establish a drift on the standing wave such that particles are preferentially diverted towards a collection zone.

Preferably the means for generating the acoustic beams includes an ultrasonic transducer. The standing wave pattern may be advantageously set up by interference between the beam generated by a single ultrasonic transducer and the reflection of the beam from a surface placed in the path of the beam. Preferably the means for controlling the acoustic beam include a signal generator, the controlling signal from which may be varied slightly in frequency to establish a drift on the standing wave in accordance with the present invention.

Alternatively opposing ultrasonic transducers may be used to generate the interfering acoustic beams. In this case drift on the standing wave may be established by phase difference between the controlling signals fed to opposing transducers.

Preferably the collection zone includes an area of modified or reduced flow and means for retaining particles, such as a conventional filter or an attractive magnetic or electrostatic field.

It will be appreciated by those skilled in the art that the standing wave may advantageously be set up substantially normal to the direction of fluid flow. It will further be appreciated that the degree of particle deviation may be reinforced by setting up a plurality of standing waves drifting in the same sense.

In order that features and advantages of the present invention may be more fully appreciated the following embodiment will now be described with reference to the accompanying diagrammatic drawings (Fig. 1a, b) which represents a filter in accordance with the present invention.

A filter for the separation of particles from a fluid 12 flowing in a pipe 10 incudes an ultrasonic transducer 11 for generating an acoustic beam within the fluid 12. An opposing ultrasonic transducer 14 generates an acoustic beam which interferes with the acoustic beam generated by the transducer 11 to set up a standing wave pattern across the direction of fluid flow in the space between the transducers 11 and 14. The standing wave pattern gives rise to pressure gradients within the fluid to divert particles carried by the fluid. A plot of pressure (P) against distance (d) across the pipe 12 in the space between the transducers 11 and 14 is represented by the profile 15 of Fig. 1(a).

Transducers 11 and 14 are driven by signal generators 16 and 17 respectively and are for convenience represented as sinusoidal oscillators. The phase angle between the controlling signals from signal generators 16 and 17 may be controlled by means known in the art to establish drift on the standing wave pattern. This control is represented by the block 18. Thus the generation of the acoustic beams may be controlled to establish a drift on the standing wave pattern away from the transducer 11 and toward transducer 14.

It will be appreciated that the drift on the standing wave pattern may be chosen such that a particle flowing with the fluid 12 will encounter a pressure gradient such that it is diverted preferentially towards a collection zone 19 situated downstream of the transducers 11 and 14. A particle such as particle 20 carried by the fluid will be diverted by the mechanism described above towards the collection zone 19, as indicated by the path 21. In this embodiment metallic particles are retained at the collection zone under the influence of a magnetic collector 22. The collector 22 is removeable to facilitate removal of collected particles.

It will be appreciated that a filter in accordance with the present invention provides separation of particles from a flowing fluid with substantially no interruption of flow.

It will further be appreciated that ultrasonic transducers as described above may be mounted externally on a pipe carrying the fluid flow, thereby easing the problem of fitting a filter to

existing systems. Collection of particles may be achieved by an externally mounted magnet. The pipe being periodically purged to remove collected particles. Alternatively transducers may be mounted in a container having a collection zone, such a container may be used as a replacement for an existing cartridge filter of the element type.

It will be realised that a filter in accordance with the present invention provides filtration to the degree currently desired for lubrication systems but that the application of the invention is not so limited. It will further be realised that by choice of frequency and amplitude of the acoustic beams a filter in accordance with the present invention filtration of sub-micronic particles may be achieved. Such filtration is of use, for example, in fuel feed systems for combustion engines where it has been established that removal of sub-micronic contaminating particles from the fuel leads to a cleaner engine exhaust. A filter in accordance with the present invention may also be arranged, for example, to filter particles or droplets of contaminating fluid from the flowing fluid.

It can be shown that the deviation produced in the path of a particle is a function of the diameter of the particle such that there is a limiting size of particle which will be diverted for collection, particles less than that size being uncollected. Further, choosing the wavelength of the acoustic beams an upper limit on the size of particle affected may be imposed, particles larger than the wavelength of the acoustic beams passing the standing wave pattern unaffected. Thus a filter in accordance with the present invention may be arranged for example to filter a band of particle sizes selectively.

Claims

1. A filter for the separation of particles from a flowing fluid including means for generating acoustic beams within the fluid which interfere with the flow to set up a standing wave pattern across the direction of flow, the standing wave producing pressure gradients within the fluid to divert particles carried by the fluid, and means for controlling the generation of the acoustic beams to establish a drift on the standing wave such that particles are preferentially diverted towards a collection zone.

2. A filter as claimed in claim 1 and wherein the means for generating the acoustic beams includes an ultrasonic transducer.

3. A filter as claimed in claim 1 or claim 2 and wherein the standing wave pattern is set up by interference between an acoustic beam and the reflection of the beam from a surface placed in the path of the beam.

4. A filter as claimed in claim 1, claim 2 or claim 3 and wherein the means for generating the acoustic beams includes a signal generator, the signal from which may be varied in frequency to establish drift on the standing wave.

5. A filter as claimed in any preceding claim and wherein opposing ultrasonic transducers generate the interfering acoustic beams.

6. A filter as claimed in claim 5 and wherein standing wave drift is established by a phase difference between acoustic beams from each transducer.

7. A filter as claimed in any preceding claim and wherein the standing wave is set up substantially normal to the direction of flow.

8. A filter as claimed in any preceding claim and wherein deviation is reinforced by a plurality of standing waves drifting in the same sense.

9. A filter as claimed in any preceding claim and wherein the means for generating the acoustic beams is mounted externally to a fluid flow pipe.

10. A filter as claimed in any preceding claim and wherein the wavelength of the standing wave is chosen to selectively divert particles of a selected size.

11. A filter substantially as hereindescribed with reference to the accompanying drawings.

12. A lubrication system including a filter as claimed in any preceding claim.

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